

FACTORS AFFECTING PIPING PLOVER PRODUCTIVITY ON ASSATEAGUE ISLAND

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Abstract: We studied piping plovers (*Charadrius melodus*) on Assateague Island (Md., Va.) in 1986–87 to estimate population size and to identify factors affecting productivity. Fledging rates (0.19–1.11 chicks/pair) appeared to be lower than the level necessary to maintain a stable population. Fifty-four percent of the nests were unsuccessful. Predators accounted for most (91%) of the known causes of nest losses. Only 1 nest (2.2% of losses with known cause) was lost due to direct human destruction, and we found no evidence that suggested recreational disturbance was a factor affecting productivity. Mean chick fledging success was 69% for broods foraging at bay flats or tidal pools and 19% for broods foraging on ocean beach ($P < 0.05$).

J. WILDL. MANAGE. 55(3):525–531

Piping plovers were listed as threatened throughout their Atlantic coastal breeding range (Newf. to S.C.) in 1986 due to concern about population declines. Declines have been attributed to loss of breeding habitat and poor productivity (U.S. Fish Wildl. Serv. [USFWS] 1988). Factors thought to be contributing to habitat loss include beach development, dune reclamation and beach stabilization, and recreational use (Wilcox 1959, Cairns and McLaren 1980). Low productivity has been attributed to recreational disturbance and high nest predation (Cairns and McLaren 1980, Cairns 1982, Flemming et al. 1988, MacIvor et al. 1990). Nest predation has been linked to nesting habitat characteristics including nesting substrate, amount of vegetative cover, and beach width (Burger 1987, Gaines and Ryan 1988).

We studied piping plovers on Assateague Island in Virginia and Maryland. Our objectives were to (1) estimate population size, (2) estimate nest success, (3) examine the influence of habitat characteristics on nest predation, (4) estimate chick survival, and (5) identify factors influencing chick survival.

We thank the National Park Service, the Virginia Department of Game and Inland Fisheries, and the Virginia Society of Ornithology for funding. Thanks also go to P. A. Buckley, J. F. Karish, R. B. Rodgers, and K. A. Terwilliger for support. D. F. Stauffer and J. D. Wellman provided criticism.

STUDY AREA

Assateague Island is a 7,700-ha barrier island off the coast of Maryland and Virginia (Fig. 1).

The island includes Assateague Island National Seashore, Assateague State Park, and Chincoteague National Wildlife Refuge. The study area encompassed the Maryland portion of the island in 1986 and the entire island in 1987. In 1987, Assateague supported 100% of the known piping plover breeding population in Maryland and 46% of the estimated breeding population in Virginia (A. Hecht, USFWS, Newton Corner, Mass., unpubl. data).

We found nesting activity in 4 areas: (1) the northernmost 11 km of Maryland, (2) 4.3 km of Wild Beach, (3) Wash Flats, and (4) Tom's Cove Hook (Fig. 1). A single pair nested in an overwash gap 1 km north of the Maryland/Virginia state line. Over much of the northern nesting area and portions of Tom's Cove Hook, the ocean and bay are separated only by sparsely vegetated sand beaches. In the remaining areas, the ocean and bay are separated by dense zones of shrub and/or forest vegetation. All nesting areas except Wash Flats are sandy beaches adjacent to the ocean. Wash Flats is a waterfowl impoundment that is separated from both the ocean and bay by zones of dense vegetation. This impoundment contains little standing water during the spring and summer and provides an unvegetated substrate used by shorebirds for nesting.

Recreationists were allowed to operate off-road vehicles (ORV's) on Tom's Cove Hook and on the southernmost 21 km in Maryland (Fig. 1). On Tom's Cove Hook, fence posts connected by iron cable were used to keep pedestrians and vehicles from entering plover nesting habitat. Generally, this fence restricted recreationists to a narrow zone above the ocean's wrack line—

the layer of debris that accumulates above the high tide mark. In the Maryland ORV zone, vehicles were not permitted on dunes, and fencing prevented ORV access to most overwash gaps in the dune line. Foot traffic was permitted in overwash gaps.

On remaining sections of the island, recreational access to beaches was limited to foot traffic. Signs instructing visitors not to enter plover nesting areas were placed above the wrack line along 2 1.5-km sections of Wild Beach in Virginia, but no other potential nesting areas were protected. Researchers and agency personnel could operate vehicles in these areas, but vehicles were kept on or immediately adjacent to the high energy beach (the portion of the beach subject to wave action throughout the tidal cycle) in areas where birds nested.

METHODS

During April 1986 and 1987, we searched potential nesting habitat between the ocean wrack line and the continuous vegetation zone once every 4–6 days. Beginning in May, surveys were conducted less frequently in areas where no plovers or plover tracks had been observed previously. During June, we surveyed only those areas where plovers had been observed. We stopped surveying during the third week in July. We began to search the Wash Flats area in mid-May when plovers were first observed using this area, and continued the surveys once every 6–7 days until the third week in July.

We estimated the breeding population based on the number of first nests found. This required distinguishing renests from first nests. In general, we considered a nesting attempt to be a renest if it was initiated after a nest loss in the same proximity and there were no observations indicating the presence of another pair prior to loss of the first nest. Because of possible bias inherent in assuming second nesting attempts of unmarked birds (some new nests close to unsuccessful nests could have been initiated by different birds), our estimates should be viewed as minimum breeding population estimates.

To determine nest success and hatch dates, nests were observed daily in 1986 and on alternate days in 1987. Usually, observations were ≤ 5 minutes long and were made from points ≥ 60 m from the nest. We considered a nest successful if ≥ 1 egg hatched. If we found no evidence of chicks, we considered a nest to be unsuccessful. We used Mayfield's (1975) method

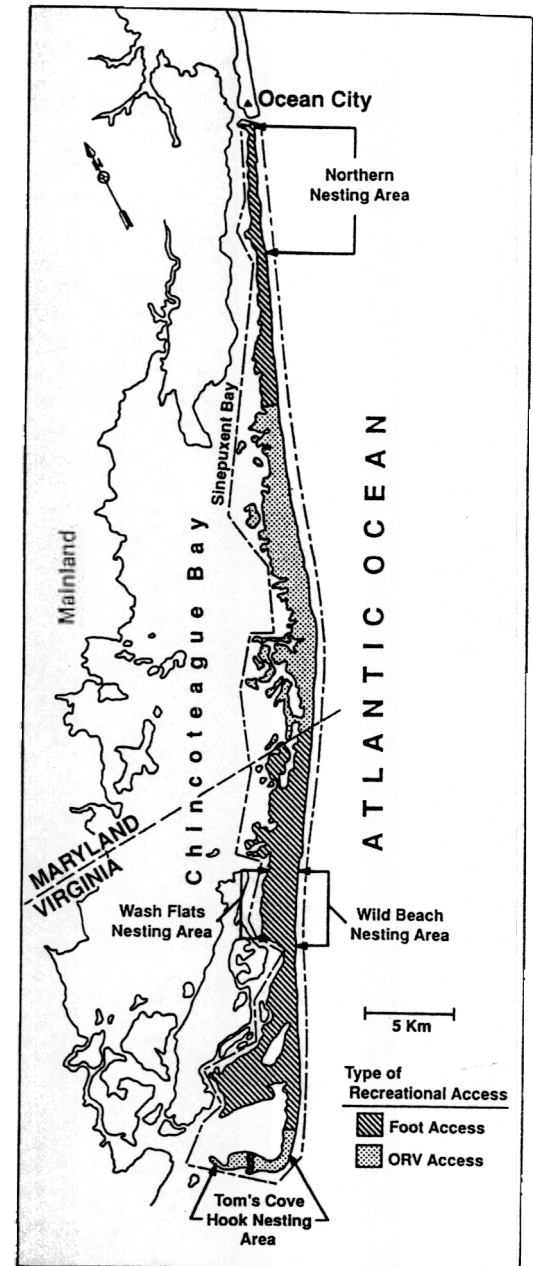


Fig. 1. Piping plover nesting areas on Assateague Island, 1986–87.

and a 34-day egg laying/incubation period to calculate overall nest success rates.

We identified nest predators on the basis of tracks and the remains of eggshells. The cause of nest loss was defined as "unknown" unless predator or human tracks leading to within 0.5 m of the nest could be located, with 2 exceptions.

Table 1. Piping plover productivity on Assateague Island, 1986–87.

Area	Nests (n)	% nest success ^a	% chick survival ^b	Chicks fledged/pair
Maryland				
Northern 11 km	53	39.4	53.8	1.11 ^c
Off-road vehicle section	3	58.5	60.0	1.50 ^c
Virginia				
Wild Beach	23	18.2	8.3	0.20 ^d
Wash Flats	22	83.5		
Tom's Cove Hook	24	9.4	50.0	0.19 ^c

^a Calculated using Mayfield's (1975) method and a 34-day egg laying/incubating period.

^b Number of chicks hatched/number of chicks fledged.

^c Based on number of nesting pairs.

^d Based on number of successful nests. Some pairs that lost nests in this area re-nested on Wash Flats.

One nest loss was attributed to the overwashing tides. At a second nest, no tracks were found, but we located a piping plover eggshell exhibiting damage characteristic of avian predation 2 m from the nest. Thus, the loss was attributed to avian predation. A Chi-square test was used to examine differences in causes of nest loss.

To determine fledging success, we observed broods daily for the first week after hatch and every other day thereafter. All chicks that disappeared before an age of 24 days were presumed not to have fledged, whereas those located at an age ≥ 24 days were considered fledged (Gaines and Ryan 1988, Patterson 1988). We used a Mann-Whitney *U*-test to compare fledging success in areas with and without ORV use. A Kruskal-Wallis test and subsequent multiple comparison tests (Zar 1984) were used to compare fledging success in different foraging habitats.

We measured vegetative cover at nest sites with a 1.0- × 0.5-m grid. The area around the nest was divided into 4 quadrants. In each quadrant, we extended a 12-m transect from a randomly selected angle beginning at the nest. Three randomly selected plots were then sampled along each transect. We used 5 cover classes (0–5%, 5–25%, 25–50%, 50–75%, and 75–100%) to estimate percent cover by grass, forbs, shrubs, and dead vegetation. We calculated average percent vegetative cover for the nest site by (1) assigning each 1.0- × 0.5-m plot a value equal to the midpoint of the estimated vegetation cover class (e.g., 2.5% for the 0–5% class), (2) adding the values of all 12 plots, and (3) dividing by 12. We also measured beach width as the sum of

distances from the nest to the wrack line and to continuous vegetation.

We used a Mann-Whitney *U*-test to compare the percent vegetative cover and percent sand cover at nests lost to predators and those not lost to predation; we used a *t*-test to make a similar comparison for beach width. Hensler's (1985) test was used to examine whether nest survival (calculated with Mayfield's [1975] method) was the same on pure sand substrates versus substrates composed of sand, shell, and cobble.

RESULTS

Population Estimates and Nest Success

The estimated breeding population on the Maryland portion of Assateague Island in 1986 was 17 pairs. In 1987, the estimated population in Maryland was 23 pairs, and the Virginia population estimate was 46 pairs.

We found 125 nests during 1986 and 1987. We also found 3 broods from unlocated nests in 1987. Nest success was highest ($P < 0.001$) on Wash Flats (84%) and lowest on the Hook (9%) (Table 1).

Factors Influencing Nest Success

Nest Predation.—Predation was the most important cause of nest loss, accounting for 91% of all known causes of nest failures ($\chi^2 = 69.71$, 2 df, $P < 0.001$) and was the only factor causing > 1 loss (Table 2). Even when unknown causes are included, 63% of all nest failures ($n = 67$) were losses due to predators. Nest predators ($n = 42$) included red foxes (*Vulpes vulpes*, 47.6%), raccoons (*Procyon lotor*, 28.6%), unidentified mammalian predators (9.5%), and avian predators (14.3%). Red foxes were the primary predators in Maryland (12 of 17 nests) and on the Hook (8 of 11 nests). Raccoons were the major predators on Wild Beach (11 of 14 nests). No predation was observed on Wash Flats.

Predation and Nest Habitat Characteristics.—Within nesting areas, mean percent vegetative cover at predated nests did not differ from cover at other nests (Table 3). In Maryland, probability of nest success was higher on pure sand substrates than on substrates with a mixture of sand, shell, and cobble, but no difference existed in Virginia (Table 4). The percentage of sand in the substrate did not differ between nests lost to predators and other nests (Table 3). Nest survival rates were similar on the widest and narrowest nesting areas (Wild Beach and Tom's

Table 2. Probable causes of piping plover nest loss, Assateague Island, 1986–87.

Area	Nest losses (n)	Cause of loss (n)			
		Predator	ORV ^a	Other ^b	Unknown
Maryland					
Northern 11 km	25	17	0	1	7
ORV section	1	0	0	0	1
Virginia					
Wild Beach	18	14	0	0	4
Wash Flats	2	0	0	1	1
Tom's Cove Hook	21	11	1	1	8
Island					
Total losses	67	42	1	3	21

^a Off-road vehicle.^b Other causes of nest loss were high tides (n = 1), wild pony (*Equus caballus*) (n = 1), and destruction of own eggs (n = 1).

Cove Hook). Within nesting areas, beach width did not differ between nests lost to predators and other nests (Table 3).

Recreational Disturbance/Destruction.—We found no evidence that recreational activities caused nest desertion. The only nest abandonment occurred in late April after a storm apparently destroyed 2 of 3 eggs in the clutch. The only nest destroyed by recreationists was run over by a vehicle on Tom's Cove Hook (Table 2). Although causes of 21 nest losses (31%) were not identified, at 10 of these nests we believe the cause to be something other than human destruction because signs of human activity were not evident. At the remaining nests, wind or rain erased evidence of the nest's fate.

Chick Survival and Fledging Rate

Chick survival ranged from 8 to 60% (Table 1). We were unable to estimate fledging success on Wash Flats because broods used common

foraging areas and therefore individual broods could not be distinguished. Most chick mortality (79%) occurred during the first 10 days after hatching. One chick was killed by a car on a road in Maryland. We were not able to specifically identify the agents responsible for the death of other chicks. Reproductive rate (chicks fledged/nesting pair) varied from 0.19 to 1.50 (Table 1).

Fledging success did not differ between areas with and without recreational ORV use (Table 5). However, fledging success differed by type of foraging habitat used (Table 5). Broods that fed primarily on bayside sand and mudflats had a higher survival rate than broods that did not have access to these areas and fed primarily on the high energy beach. Seven of 12 broods in the high energy beach category fledged no chicks, whereas only 3 of 19 broods in the bay category fledged no chicks. Seventy-nine percent of the chicks in the high energy beach

Table 3. Percent vegetative cover, percent sand cover, and beach width (m) at piping plover nests destroyed by predators, and other nests, Assateague Island, 1986–87.

Area		% vegetative cover		% sand cover		Beach width (m)	
		\bar{x}	P^a	\bar{x}	P^b	\bar{x}	P^b
Maryland							
Predated nests	17	7.90	0.09	76	0.99	251	
Other nests	31	8.07		76		226	
Wild Beach							
Predated nests	14	19.26	0.40	95	0.84	153	
Other nests	5	14.83		97		171	
Tom's Cove Hook							
Predated nests	11	11.23	0.70	87	0.63	275	0.10
Other nests	3	12.29		70		424	

^a Based on Mann-Whitney U-test.^b Based on t-test.

Table 4. Probability of nest survival for piping plover nests on different substrates, Assateague Island, 1986–87.

Area	Nests (n)	Probability of nest survival	P ^a
		0.6036 0.2779	0.021
		0.1512 0.3837	0.388
		0.7372 0.8802	0.569
		0.1679 0.0573	0.326

category ($n = 33$) died during the first 10 days of life, whereas only 13% of the chicks in the bay category ($n = 53$) died during this period.

DISCUSSION

Reproductive Rate

Based on survival rates of adult piping plovers from North Dakota, Gaines and Ryan (1988) estimated that between 1.15 and 1.44 chicks must be fledged per pair to maintain a stable population. This estimate suggests that the reproductive rate in Maryland was slightly lower than necessary to maintain a stable population, whereas the observed reproductive rates on Wild Beach and Tom's Cove Hook were much lower than the required level.

Nest predation was the major factor contributing to low productivity. Although nest predation has been identified as a leading cause of piping plover nest loss in other studies (Britton 1982, MacIvor *et al.* 1990), the question of why it has become a major factor in the decline of this population has not been addressed. Red fox predation might not have been an historic problem because this species may not be native to the East Coast (Churcher 1959). Also, predation pressure might have increased because predators are attracted by garbage and foodscraps left by recreationists (Fed. Register 1985). Finally, human-induced changes in breeding habitat might have increased predation. Loss of nesting habitat due to beach development could force plovers to nest in areas that would otherwise be avoided due to high predation pressure. Also, habitat changes associated with beach stabi-

Table 5. Mean percentage of chicks fledging in piping plover broods, Assateague Island, 1986–87.^a

	n	\bar{x}	SE
Type of recreational access			
ORV use allowed	5	56.7A ^b	19.44
ORV use not allowed	33	48.2A	6.92
Type of foraging habitat			
Bay	20	69.2A ^c	7.95
Tidal pool	3	66.7AB	16.67
Miscellaneous	3	22.2AB	11.11
High energy beach ^d	12	18.8B	8.59

^a Means within a category with the same letters are not different ($P \geq 0.05$).

^b Mann-Whitney *U*-test results (corrected for ties).

^c Kruskal-Wallis (corrected for ties) and subsequent multiple comparison test results (Zar 1984).

^d The high energy beach is the portion of the beach subject to wave action throughout the tidal cycle.

zation such as narrower beaches, increased vegetation growth, and less shelly substrates (Dolan 1973, Godfrey and Godfrey 1973) might increase predation. However, on Assateague, we found no consistent relationship between nest predation and nest habitat characteristics. Finally, bridges from the mainland to the island may have altered predator populations by increasing immigration rates to the island.

Human Activity and Nest Success

Many previous observations linking human disturbance to decreased nest success involve direct mortality (USFWS 1988). The one-strand cable fencing on Tom's Cove Hook provided protection from direct destruction. Since 1978 when these fences were first constructed, none of the piping plover nests within the fences is known to have been lost to direct human destruction (Britton 1982; I. Ailes, Chincoteague Natl. Wildl. Refuge., unpubl. data). The indirect effects of human activities on nest success are not understood (Patterson *et al.* 1990). However, there is some evidence suggesting that piping plovers can become habituated to human activity on nesting beaches (Cairns and McLaren 1980, Flemming 1984).

Chick Survival

Chick mortality on Assateague appeared to be substantial; however, high prefledging mortality rates appear to be typical for the Charadrii (Boyd 1962, Harris 1967, Pienkowski 1984, Warriner *et al.* 1986, Byrkjedal 1987). Of the 3

major nesting areas on Assateague for which we estimated chick survival, only Wild Beach fell substantially below survival rates reported for other *Charadrii*.

Little is known about factors responsible for piping plover chick mortality. Low chick survival is frequently attributed to recreational disturbance which is thought to disrupt essential feeding activity in addition to causing direct mortality (Cairns and McLaren 1980, Flemming et al. 1988). Differences in chick survival among foraging habitats on Assateague could have been due to differences in the availability and/or quality of prey. Differences in predation pressures among the foraging habitats could also account for the differential chick mortality. Also, these 3 factors—quality of the foraging areas, predation rates, and human disturbance—might interact to produce differences in chick survival.

MANAGEMENT IMPLICATIONS

Efforts to improve piping plover productivity on Assateague should focus on reducing nest predation. Patterson et al. (1990) discuss 2 methods of predator control (predator removal and predator exclosures). However, because predator control efforts are labor intensive and do not provide a long-term solution, future efforts should examine factors influencing predation rates. A specific goal of predation studies should be to determine the extent to which human activities (e.g., recreation behaviors, habitat changes resulting from beach stabilization, etc.) influence predation. The absence of nest predation on Wash Flats, a man-made nesting area, suggests that creating breeding habitat in areas with lower predation rates should be explored.

Fencing is an effective means of eliminating direct destruction of nests by people. Because piping plovers typically nest far above the high tide line (Burger 1987, Patterson 1988) and appear capable of habituating to some levels of recreational activity, restricting recreational use to narrow zones immediately adjacent to the high energy beach might reduce indirect recreational disturbance to plovers nesting on beaches with a wide berm (Patterson et al. 1990). However, foraging areas used by the plovers should be identified. On beaches where plovers forage primarily on the high energy beach, it may be necessary to close the beach to recreational use even if nest sites can be adequately protected.

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Received 26 February 1990.

Accepted 4 March 1991.

Associate Editor: Smith.